PHENIX results for J/ψ transverse momentum and rapidity dependence in Au+Au and Cu+Cu collisions

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Abstract. The PHENIX experiment at RHIC has measured J/ψ production in $\sqrt{s_{NN}}$ = 200 GeV Au+Au and Cu+Cu collisions at forward ($1.2 < |y| < 2.2$) and mid ($|y| < 0.35$) rapidities. The most recent results for the rapidity and transverse momentum dependence of J/ψ production are presented and compared with PHENIX baseline p+p measurements and selected theoretical calculations. We find that J/ψ production is significantly more suppressed, as compared to p+p, at forward rapidity than mid rapidity in central Au+Au collisions.

1. Introduction

Heavy quarkonia production is considered to be one of the most important probes of the hot and dense state created in relativistic heavy ion collisions. At RHIC energy J/ψ yields, especially the contributions from χ_c and ψ' states, are expected to be suppressed in a quark gluon plasma due to color screening and gluon rescattering [1, 2]. Intriguing measurements of J/ψ suppression at lower energies have been reported from CERN-SPS experiments [3, 4], At $\sqrt{s_{NN}}$ = 200 GeV competing processes such as quark recombination may also play an important role. Detailed models with different production and suppression contributions may generate similar centrality trends while presenting distinctions in rapidity and/or transverse momentum distributions. For example, J/ψ recombination from thermalized quarks could be more evident in transverse momentum modifications.

2. Experiment and Analysis

Electron pairs are measured in the PHENIX central arm spectrometers which together cover the J/ψ rapidity range $|y| < 0.35$ and 180 degrees in azimuth. Muon pairs are measured using the two forward spectrometers which cover $1.2 < |y| < 2.2$ with full azimuthal acceptance. Please see [5] for more details on the PHENIX experiment.

‡ For the full list of PHENIX authors and acknowledgements, see Appendix 'Collaborations' of this volume

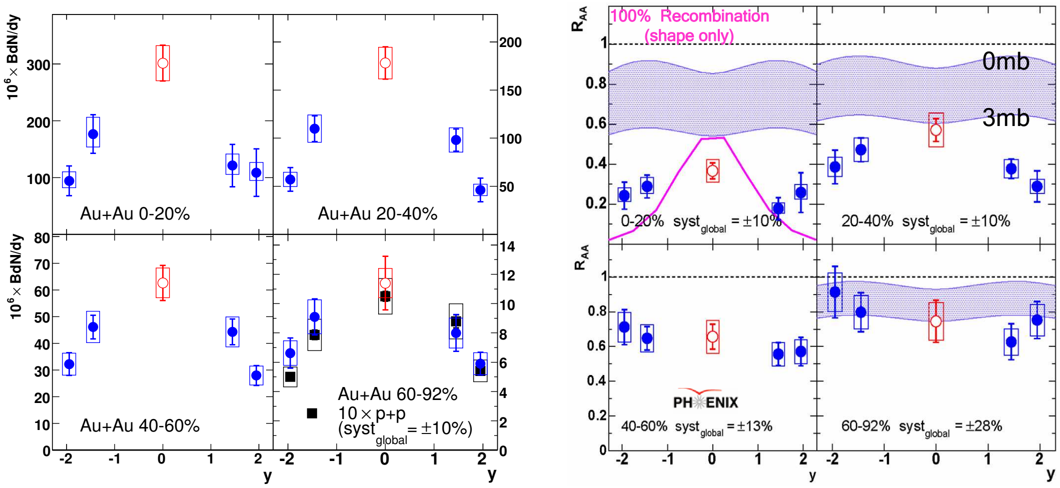

Figure 1. (Left) J/ψ invariant yield vs. y for several centrality bins in Au+Au collisions. Data for p+p collisions (black squares) is also shown. (Right) J/ψ R_{AA} vs. y for several centrality bins in Au+Au collisions. Cold nuclear matter calculations [9] are shown as shaded regions, and the solid line in the upper left panel is a shape calculation assuming that all J/ψ's are from recombination [11].

The J/ψ yields are extracted from the invariant mass spectra of unlike sign dileptons after subtracting the combinatorial background component as estimated from an event mixing method. The yields are additionally corrected for the dilepton continuum and loss due to the radiative tail in the case of electrons. In minimum bias Au+Au collisions approximately 1000 and 4500 J/ψ's were reconstructed from the dielectron and dimuon channels respectively. The raw J/ψ yields are corrected using acceptance and efficiency of the spectrometers and the corresponding number of recorded events to obtain the final invariant yields. Please see [6] for more information regarding the analysis.

3. Results and Discussion

Figure 1 shows the rapidity dependence of the J/ψ invariant yield and nuclear modification factor R_{AA} for four centrality classes. The $\sqrt{s}$ = 200 GeV p+p reference data used in the Au+Au analysis is from the 2005 RHIC run [7]. Although the centrality dependence of J/ψ production for this analysis is discussed in detail elsewhere [8], the centrality dependence cannot be ignored in this discussion. The most peripheral R_{AA} values appear to be consistent with cold nuclear matter (CNM) calculations [9] which use range of 0 to 3 mb for the J/ψ absorption cross section as constrained by PHENIX d+Au measurement [10]. However, the most central R_{AA} values for all rapidity are well below the CNM calculation for even the largest absorption cross section. Also, the forward rapidity R_{AA} appears to be below the mid rapidity value for more central events. Such a narrowing of the rapidity distribution is expected if a significant fraction of J/ψ's are formed from recombination of unrelated $c\bar{c}$ pairs. An estimate for the narrowed shape assuming that all J/ψ's are from recombination [11] is shown with the central data. Other scenarios such as the initial condition of a Color Glass Condensate would also result in a narrowing of the rapidity distribution [12].

The observation that the J/ψ suppression, relative to binary scaling of p+p, is larger at forward rapidity than mid rapidity becomes even more evident when looking at the ratio of $R_{AA}^{\rm forward}$ (i.e. integrated over $1.2 < |y| < 2.2$ and p_T) to $R_{AA}^{\rm mid}$ (i.e. integrated over $|y| < 0.35$ and all p_T) as shown vs. centrality in Figure 2. The double ratio shows

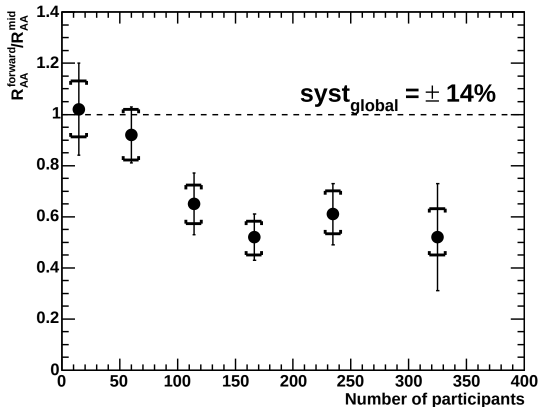

Figure 2. Ratio between the forward and mid rapidity J/ψ R_{AA} vs. $N_{\rm part}$.

that the suppression becomes greater at forward rapidity for $N_{\rm part} > 100$. The rapidity dependence of meson production in central collisions as measured by BRAHMS [13] implies a larger local density at mid rapidity. This means that models which have only J/ψ suppression based on local density [14, 15] have no hope of usefully describing $\sqrt{s}$ = 200 GeV central Au+Au collisions. Such models must at best be missing an important effect or effects such as Color Glass Condensate or recombination.

Recombination is expected to have manifestations in the J/ψ p_T distribution. Figure 3 shows PHENIX measurements of $\langle p_T^2 \rangle$ for $p_T < 5$ GeV/c for p+p, Cu+Cu [16], and Au+Au collisions as a function of centrality. The truncated $\langle p_T^2 \rangle$ can be extracted more accurately since no assumed fit functions are used to extrapolate to infinity. Two sets of calculations for $\langle p_T^2 \rangle$ centrality dependence are also shown [17, 18]. Both models show that recombination causes a significant reduction in $\langle p_T^2 \rangle$ which brings the model into better agreement with the data, but the magnitude of the effect and even the expectation without recombination varies significantly between the models. Also, according to [18], differentiating between recombination of thermally distributed or pQCD $c\bar{c}$ pairs would be very difficult.

Although not shown here, the J/ψ R_{AA} as a function of p_T appears to be fairly flat within statistics out 5 GeV/c [6]. The large high p_T heavy flavor electron suppression observed by PHENIX [19] if combined with a large recombination component could cause R_{AA} to drop at high enough p_T. An AdS/CFT correspondence calculation [20] also expects more suppression at high p_T. Increased statistics and precision calculations may support or refute of these effects. Disentangling the recombination contribution should also be aided by future PHENIX measurements of J/ψ elliptic flow.

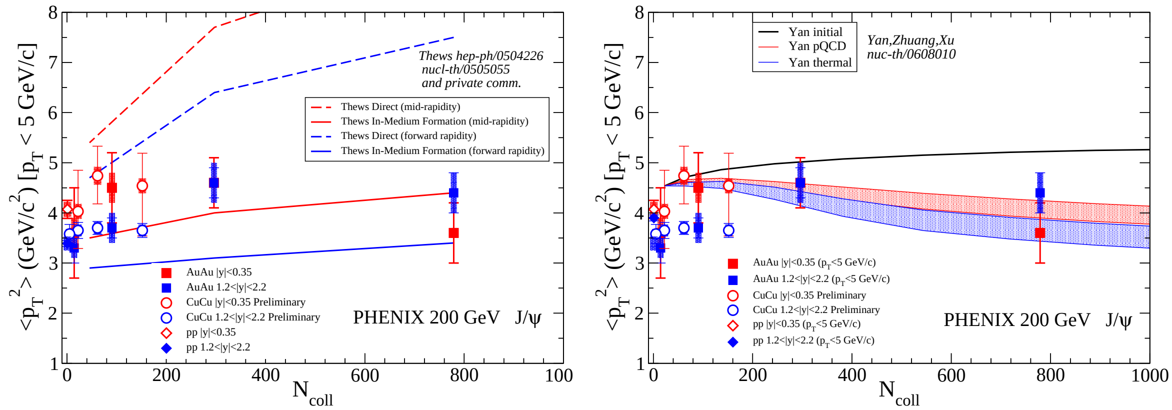

Figure 3. The $\langle p_T^2 \rangle$ for $p_T < 5$ GeV/c for p+p, Cu+Cu, and Au+Au collisions as a function of N_{coll}. Calculations for the effect of recombination are also shown [17, 18].

4. Summary and Conclusions

The PHENIX experiment at RHIC has measured J/ψ production in $\sqrt{s_{NN}} = 200$ GeV Au+Au and Cu+Cu collisions at forward ($1.2 < |y| < 2.2$) and mid ($|y| < 0.35$) rapidities. We find that J/ψ production is significantly more suppressed at forward rapidity than mid rapidity in central Au+Au collisions showing that larger local density does not necessarily imply larger suppression. J/ψ have been measured out to 5 GeV/c in p_T, and $\langle p_T^2 \rangle$ for $p_T < 5$ GeV/c shows moderate, if any, increase with N_{coll}.

References

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